

# **INDOOR AIR QUALITY ASSESSMENT**

**Wachusett Regional High School  
1401 Main Street  
Holden, Massachusetts 01520**



Prepared by:  
Massachusetts Department of Public Health  
Center for Environmental Health  
Emergency Response/Indoor Air Quality Program  
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## **Background/Introduction**

At the request of parents, the Massachusetts Department of Public Health's (MDPH), Center for Environmental Health (CEH), provided assistance and consultation regarding indoor air quality concerns at the Wachusett Regional High School (WRHS), 1401 Main Street, Holden, Massachusetts. On October 7, 2005, Cory Holmes, an Environmental Analysts for CEH's Emergency Response/Indoor Air Quality (ER/IAQ) Program, conducted an assessment of this building. Mr. Holmes was accompanied by Joyce Crouse, Health Agent for the Holden Board of Health, Sheila Frias, Principal of WRHS and Suzanne Breen, Administrative Assistant to the Building Project. At the time of the assessment, the building was under construction while occupied by students, teachers and school administrators. Concerns about indoor air quality related to construction/renovation activities, particularly in lower level classrooms, prompted the request.

The WRHS was built in the early 1950s, with a number of additions built over the years. At the time of the assessment, several areas had been demolished, and several newly constructed sections were occupied. Portions of the remaining building (e.g., lower level) were also occupied and scheduled for renovation during the winter of 2005. The gymnasium was being used to house classes, as well as the kitchen and cafeteria. In addition, several modular classrooms were constructed on-site to temporarily house displaced classes during the renovation/expansion project. Active construction was being conducted directly adjacent to the 1950s portion of the building, which had not been renovated at the time of the assessment. In addition, it was from this area of the building where indoor air quality concerns originated.

## **Methods**

MDPH staff conducted air monitoring to assess whether construction/renovation generated contaminants were migrating into occupied areas of the building. As discussed, air quality concerns originated from the 1950s portion of the building that had not undergone renovations. Therefore, air testing focused on these areas as well as interfaces (construction barriers) between occupied areas and construction zones. Measurements for ultrafine particles (UFPs) in combination with carbon monoxide (CO) measurements were taken to identify potential pathways of combustion products. Air tests for carbon dioxide, CO, temperature and relative humidity were taken with the TSI, Q-Trak, IAQ Monitor Model 8551. Air tests for ultrafine particulates were taken with the TSI, P-Trak <sup>TM</sup> Ultrafine Particle Counter Model 8525. Screening for total volatile organic compounds (TVOCs) was conducted using a Hnu, Model 102 Snap-on Photo Ionization Detector (PID).

## **Results**

The school houses approximately 1,940 students and a staff of approximately 200. Tests were taken during normal operations at the school and appear in Table 1. Renovations related results (CO, TVOCs and UFCs) appear in Table 2.

## **Discussion**

### **Ventilation**

It can be seen from Table 1 that carbon dioxide levels were above 800 parts per million (ppm) in both of the occupied lower level classrooms surveyed, as well as the cafeteria (Table 1), indicating inadequate air exchange in these areas. Mechanical ventilation in lower level

classrooms is provided by unit ventilator (univent) systems (Picture 1). A univent draws air from outdoors through a fresh air intake located on the exterior wall of the building (Picture 2) and returns air through an air intake located at the unit's base. Fresh and return air are mixed, filtered, heated and provided to classrooms through an air diffuser located in the top of the unit ([Figure 1](#)).

Although univents were activated, airflow was weak. Univents appear to be original equipment, approximately 50 or more years old. Function of such aged equipment is difficult to maintain, since compatible replacement parts are often unavailable. Airflow was also impeded by filter media installed over the air intakes on the exterior of the building (Picture 2). The filter media was installed in an effort to reduce/prevent the entrainment of construction related pollutants generated from activities adjacent to the building (Pictures 3 and 4).

Exhaust ventilation in lower level classrooms was designed to be provided by unit exhaust ventilators (Picture 5), which are much like a univent but *remove air* from the building. A unit exhaust ventilator contains a fan, which draws in and forces air out through an exhaust vent on the exterior of the building. All unit exhaust ventilators were deactivated during the assessment and appeared not to have been operated for some time. Exhaust ventilation in classroom 207 was originally provided by exhaust vents located in an ungrated "cubby hole" located at floor level (Picture 6). Classroom air is drawn into the cubby hole and vented to a rooftop motor. As with the unit exhaust ventilators, this exhaust was inoperable at the time of the assessment. Therefore, no mechanical exhaust was being provided to these classroom areas.

Elevated carbon dioxide levels (2,264 ppm) were also measured in the gym/cafeteria. Mechanical ventilation is provided by rooftop air handling units and wall-mounted exhaust vents. As with the univents, the supply system was operating weakly and the exhaust system

was inoperable. Due to the continuous/increased use of the gym for classroom space and the kitchen/cafeteria, coupled with the waste heat generated by kitchen equipment and vending machines, the existing ventilation system does not appear to be sufficient to provide proper airflow and comfort. Without adequate supply and exhaust ventilation, excess heat and environmental pollutants can build up and lead to indoor air/comfort complaints.

To maximize air exchange, the MDPH recommends that both supply and exhaust ventilation operate continuously during periods of occupancy. In order to have proper ventilation with a mechanical ventilation system, the systems must be balanced subsequent to installation to provide an adequate amount of fresh air to the interior of a room while removing stale air from the room. It is recommended that HVAC systems be re-balanced every five years to ensure adequate air systems function (SMACNA, 1994). Mechanical ventilation in the existing portions of the WRHS cannot be balanced in their current state. It is important to note however that all mechanical ventilation components are scheduled to be replaced during the renovation project. In addition, school officials reported that an HVAC engineering firm had conducted an evaluation of ventilation components in the lower level classroom in order to make temporary repairs.

The Massachusetts Building Code requires a minimum ventilation rate of 15 cubic feet per minute (cfm) per occupant of fresh outside air or have openable windows in each room (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens, a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week, based on a time-weighted average (OSHA, 1997).

The MDPH uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches. For more information concerning carbon dioxide, please consult [Appendix A](#).

Temperature measurements the day of the assessment ranged from 75° F to 83° F, with all but one area (the gym/cafeteria) within the MDPH comfort guidelines. As discussed, waste heat from kitchen equipment and vending machines and a lack of air exchange in the gymnasium can serve to increase temperature and lead to comfort complaints. The MDPH recommends that indoor air temperatures be maintained in a range of 70° F to 78° F in order to provide for the comfort of building occupants. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply. In addition, it is difficult to control temperature and maintain comfort without operating the ventilation equipment as designed (e.g., supply/exhaust ventilation not operating/operating weakly).

The relative humidity measured in the building ranged from 64 to 74 percent, which was above the MDPH recommended comfort range. The MDPH recommends a comfort range of 40 to 60 percent for indoor air relative humidity. However, these relative humidity readings would be expected with an outdoor relative humidity of 72 percent, with windows open and/or drafts through breaches in containment walls separating occupied areas from construction zones that are open to the elements (refer to the Renovations section of this report). It is also difficult to maintain relative humidity without the aid of air conditioning and/or dehumidifiers during hot, humid weather. Relative humidity in excess of 70 percent for extended periods of time can provide an environment for mold and fungal growth (ASHRAE, 1989). Relative humidity levels in the building would be expected to drop during the winter months due to heating. The sensation of dryness and irritation is common in a low relative humidity environment. Low relative humidity is a very common problem during the heating season in the northeast part of the United States.

## **Renovations**

It is important to note that the State Department of Education amended their regulations in 1999 to address concerns associated with school renovation projects in Massachusetts (MDOE, 1999). Renovation activities can produce a number of pollutants, including dirt, dust, particulates, and combustion products such as CO (i.e., from construction vehicles). CO can produce immediate, acute health effects upon exposure. Particles generated from construction activities can settle on horizontal surfaces in classrooms where they can become re-aerosolized and be a source of eye and respiratory irritation.

The US Environmental Protection Agency (US EPA) has established National Ambient Air Quality Standards (NAAQS) for exposure to carbon monoxide in outdoor air. Carbon monoxide levels in outdoor air must be maintained below 9 ppm over a twenty-four hour period in order to meet this standard (US EPA, 2000). On the day of assessment, outdoor carbon monoxide concentrations were measured at 1 ppm (Table 1). Detectable levels of carbon monoxide were measured in all areas surveyed in the building, with 2 areas showing 1 ppm and 6 areas ranging from 3 to 7 ppm (Table 2) in the lower level hallway near construction barriers.

The combustion of fossil fuels, welding, steel cutting, concrete/brick boring and other renovation activities can produce particulate matter that is of a small diameter [ $<10$  micrometers ( $\mu\text{m}$ )], which can penetrate into the lungs and subsequently cause irritation. For this reason a device that can measure ultra fine particles (UFPs), particles of a diameter of  $10\ \mu\text{m}$  or less, was used to identify pollutant pathways from the renovation site into occupied areas.

The instrument used by MDPH staff to conduct air monitoring for UFPs counts the number of particles that are suspended in a cubic centimeter ( $\text{cm}^3$ ) of air. This type of air monitoring is useful in that it can track and identify the source of airborne pollutants by counting the actual number of airborne particles. The source of particle production can be identified by moving the UFP counter through a building towards the highest measured concentration of airborne particles. Measured levels of particles/ $\text{cm}^3$  of air increase as the UFP counter is moved closer to the source of particle production.

The primary purpose of these tests at the school was to identify and reduce/prevent pollutant pathways. Air monitoring for UFPs was conducted in classrooms, hallways and other areas that may be directly impacted by renovation activities due to close proximity to these activities. For comparison (i.e., background), measurements in areas away from renovation sites

indoors as well as outdoors were taken. Increased levels of UFPs over background levels were measured around breaches in containment walls in several areas (Table 2).

In an effort to reduce airborne pollutants generated by adjacent construction, air filtration units equipped with high efficiency particulate arrestance (HEPA) filters were employed in the lower level hallway (Picture 7). However, the filtration unit was actually *drawing* construction-generated pollutants *into* the building through gaps/spaces in the construction containment wall (Pictures 8 and 9). As with the lower level construction barrier, breaches were observed in and around several other barriers from which drafts could be felt and/or light could be seen (Table 2).

A number of construction vehicles and several large piles of dirt/construction debris were observed around the perimeter of the building. This activity should be closely monitored to prevent the entrainment of vehicle exhaust and other construction generated pollutants inside the building via univents, open doors or windows. A number of classrooms adjacent to the construction zone had open windows (Picture 10). The opening of windows allows for unfiltered air to enter the classroom environment carrying with it airborne dirt, dust and particulates. Thus, opening windows should be done with caution. Dusts can be irritating to the eyes, nose and respiratory tract.

Other pathways were observed for construction-generated pollutants to enter occupied areas of the building. A temporary doorway was installed in classroom 5, which is located in the lower level. A gap was noted below the door (Picture 11); several areas around the doorway were open, allowing drafts and light into the room near the top of the doorway (Picture 12). As a result, birds had entered the classroom and built a nest on top of the temporary doorway (Picture 13).

Indoor air quality can also be impacted by the presence of materials containing volatile organic compounds (VOCs). VOCs are substances that have the ability to evaporate at room temperature. Frequently, exposure to low levels of total VOCs (TVOCs) may produce eye, nose, throat and/or respiratory irritation in some sensitive individuals. For example, chemicals evaporating from a paint can stored at room temperature would most likely contain VOCs. In an effort to determine whether VOCs were present in the building, air monitoring for TVOCs was conducted. Outdoor air samples were taken for comparison. Outdoor TVOC concentrations were ND (Table 2). Slight readings of 0.2 to 1.2 ppm were measured in the lower level hallway (Table 2). School officials reported that the concrete floor to the lower level had been sealed with a VOC-containing product on September 6, 2005, which is the most likely source of lingering VOCs.

Please note, TVOC air measurements are only reflective of the indoor air concentrations present at the time of sampling. Indoor air concentrations can be greatly impacted by the use TVOC containing products (e.g., the concentration of TVOCs within a classroom increases when the product is in use) such as dry erase markers and cleaning products. Dry erase markers were seen in several classrooms. Materials such as dry erase markers and dry erase board cleaners may contain VOCs, (e.g. methyl isobutyl ketone, n-butyl acetate and butyl-cellusolve) (Sanford, 1999). Cleaning products contain VOCs and other chemicals that can be irritating to the eyes, nose and throat of sensitive individuals.

## **Conclusions/Recommendations**

A number of pathways exist for pollutants to move from areas under renovation or construction into occupied spaces. These pathways indicate that the containment measures at the

time of the assessment were insufficient to contain pollutants related to renovation work. The following recommendations should be implemented in order to reduce the migration of renovation-generated pollutants into occupied areas and the potential impact on indoor air quality:

1. Comply with 603 CMR 38.00: School Construction – Massachusetts Department of Education. This regulation states that “[a]pplicants shall implement containment procedures for dusts, gases, fumes, and other pollutants created during renovations/construction as part of any planned construction, addition to, or renovation of a school if the building is occupied by students, teachers or school department staff while such renovation and construction is occurring. Such containment procedures shall be consistent with the most current edition of the IAQ Guidelines for Occupied Buildings Under Construction published by the Sheet Metal and Air Conditioning Contractors National Association, Inc. (SMACNA). All bids received for school construction or renovations shall include the cost of planning and execution of containment of construction/renovation pollutants consistent with the SMACNA guidelines [608 CMR 38.03(13)] General Requirements: Capital Construction” (MDOE, 1999).
2. Operate all ventilation systems (that are operable) throughout the building (e.g., gym, auditorium, classrooms) continuously during periods of school occupancy to maximize air exchange. Continue with plans to make repairs to mechanical ventilation components in the lower level.
3. Work with the architect, general contractor and/or an HVAC engineering firm to examine options to improve air exchange and reduce heat in the gymnasium.

4. Seal around exterior doors with weather stripping and door sweeps. Seal construction barriers on all sides with polyethylene plastic and duct tape. Seal these barriers on the construction as well as the occupied side to provide a dual barrier. Ensure integrity of barriers by monitoring for light penetration and drafts around seams.
5. Inspect classrooms for cleanliness and construction barriers for integrity *daily* prior to the opening of school. Consideration should also be given to inspect construction barriers at the end of the school day prior to construction work. In addition, encourage school staff to report any breaches in construction barriers immediately to the main office during the school day.
6. Seal and insulate the temporary doorway in classroom 5.
7. Remove bird's nest in classroom 5, and disinfect with an appropriate antimicrobial where necessary.
8. Use local exhaust ventilation and isolation techniques to control for renovation pollutants. Precautions should be taken to avoid the *re-entrainment* of these materials into the building's HVAC system. The design of each system must be assessed to determine how it may be impacted by renovation activities. Specific HVAC protection requirements pertain to the return, central filtration and supply components of the ventilation system. This may entail shutting down systems (when possible) during periods of heavy construction and demolition, ensuring systems are isolated from contaminated environments, sealing ventilation openings with plastic and utilizing filters with a higher dust spot efficiency where needed (SMACNA, 1995).

9. Implement prudent housekeeping and work site practices to minimize exposure to renovation pollutants. Consider increasing the number of full-time equivalents or work hours for existing staff (e.g., before school) to accommodate increase in dirt, dust accumulation due to construction/renovation activities. To control for dusts, a high efficiency particulate air (HEPA) filter equipped vacuum cleaner in conjunction with wet wiping/mopping of all surfaces is recommended.
10. Develop a notification system for building occupants immediately adjacent to construction activities to report construction/renovation related odors and/or dusts problems to the building administrator. Have these concerns relayed to the contractor in a manner to allow for a timely remediation of the problem.
11. Schedule projects that produce large amounts of dusts, odors and emissions during unoccupied periods or periods of low occupancy when possible.
12. Cover dirt/debris piles with tarps or wet down to decrease aerosolization of particulates, when possible.
13. Ensure the faculty is aware of construction activities that may be conducted in close proximity to their classrooms. In certain cases, HVAC equipment and windows to classrooms adjacent to construction activities may need to be deactivated/closed periodically to prevent unfiltered air and vehicle exhaust from entering the building. For this reason, prior notification(s) should be made.
14. Disseminate scheduling itinerary to all affected parties; this can be done in the form of meetings, newsletters or weekly bulletins.

15. Obtain Material Safety Data Sheets (MSDS) for all construction materials used during renovations and keep them in an area that is accessible to all individuals during periods of building operations as required by the Massachusetts Right-To-Know Act (MGL, 1983).
16. Consult MSDS' for any material applied to the affected area during renovation(s) including any sealant, carpet adhesive, tile mastic, flooring and/or roofing materials. Provide proper ventilation and allow sufficient curing time as per the manufacturer's instructions concerning these materials.
17. If possible, relocate susceptible persons and those with pre-existing medical conditions (e.g., hypersensitivity, asthma) away from areas of renovations.
18. Consider changing HVAC filters more regularly in areas impacted by renovation activities. Examine the feasibility of acquiring more efficient filters for these units.
19. Refer to resource manuals and other related indoor air quality documents for further building-wide evaluations and advice on maintaining public buildings. Copies of these materials are located on the MDPH's website: [http://mass.gov/dph/indoor\\_air](http://mass.gov/dph/indoor_air)

## References

- ASHRAE. 1989. Ventilation for Acceptable Indoor Air Quality. American Society of Heating, Refrigeration and Air Conditioning Engineers. ANSI/ASHRAE 62-1989
- BOCA. 1993. The BOCA National Mechanical Code/1993. 8<sup>th</sup> ed. Building Officials and Code Administrators International, Inc., Country Club Hill, IL.
- MDOE. 1999. School Construction, General Requirements: Capital Construction 603 CMR 38.03(13). Massachusetts Department of Education, Malden, MA.
- MGL. 1983. Hazardous Substances Disclosure by Employers. Massachusetts General Laws. M.G.L. c. 111F.
- OSHA. 1997. Limits for Air Contaminants. Occupational Safety and Health Administration. Code of Federal Regulations. 29 C.F.R 1910.1000 Table Z-1-A.
- Sanford. 1999. Material Safety Data Sheet (MSDS No: 198-17). Expo® Dry Erase Markers Bullet, Chisel, and Ultra Fine Tip. Sanford Corporation, Bellwood, IL.
- SBBRS. 1997. Mechanical Ventilation. State Board of Building Regulations and Standards. Code of Massachusetts Regulations. 780 CMR 1209.0.
- SMACNA. 1994. HVAC Systems Commissioning Manual. 1<sup>st</sup> ed. Sheet Metal and Air Conditioning Contractors' National Association, Inc., Chantilly, VA.
- SMACNA. 1995. IAQ Guidelines for Occupied Buildings Under Construction. 1<sup>st</sup> ed. Sheet Metal and Air Conditioning Contractors' National Association, Inc., Chantilly, VA.
- US EPA. 2000. National Ambient Air Quality Standards (NAAQS). . US Environmental Protection Agency, Office of Air Quality Planning and Standards, Washington, DC.  
<http://www.epa.gov/air/criteria.html>.

**Picture 1**



**Classroom Univent in Lower Level Classroom, Circa 1950**

**Picture 2**



**Univent Air Intake for Lower Level Classroom Covered with Filter Media**

**Picture 3**



**Construction Activity Adjacent to Lower Level Classrooms**

**Picture 4**



**Construction Activity Adjacent to Lower Level Classrooms, Picture Taken from Inside Classroom**

**Picture 5**



**Unit Exhaust Ventilator in Lower Level Classroom**

**Picture 6**



**Exhaust Cubby for Classroom 207**

**Picture 7**



**HEPA Filtration Unit in Lower Level Hallway, Note Flexible Ductwork Forcing Air *towards* Classrooms**

**Picture 8**



**Breach in Construction Containment Wall in Lower Level Hallway**

**Picture 9**



**Space beneath Construction Containment Wall in Lower Level Hallway**

**Picture 10**



**Operating Construction Vehicle outside Classroom 207**

**Picture 11**



**Space under Exterior Door in Classroom 5, Lower Level**

**Picture 12**



**Spaces around Wood for Temporary Doorway in Classroom 5**

**Picture 13**



**Birds Nest on top of Temporary Doorway *inside* Classroom 5**

TABLE 1

**Indoor Air Test Results – Wachusett Regional High School, Holden, MA – October 7, 2005**

Location	Carbon Dioxide (*ppm)	Temp. (°F)	Relative Humidity (%)	Occupants in Room	Windows Openable	Ventilation		Remarks
						Supply	Exhaust	
Background at Front Entrance	456	75	72					Warm, humid, cloudy, cars idling, construction activity
2 <sup>nd</sup> Floor Hallway Center	693	77	69	0	0	N	N	
2 <sup>nd</sup> Floor Boys Restroom					Y	N	Y	Cigarette smoke, exhaust vents not operating
9	1,129	77	70	15	Y	Y	Y	UV-on, exhaust-off
7	1,005	78	70	21	Y	Y	Y	UV-weak, exhaust-off
5	487	75	74	1	Y	Y	Y	Birds nest over temporary doorway-open spaces to the outside, space under exterior door, exhaust-off, class at lunch
207	449	76	64	0	Y	Y	Y	Windows open, construction vehicles operating, UV and exhaust vent-not operating
Cafeteria/gym	2,264	83	71	200	N	Y	N	Stuffy, hot, exhaust inoperable, kitchen equipment/vending machines-waste heat

\* ppm = parts per million parts of air

**Comfort Guidelines**

Carbon Dioxide - < 600 ppm = preferred  
600 - 800 ppm = acceptable  
> 800 ppm = indicative of ventilation problems

Temperature - 70 - 78 °F

Relative Humidity - 40 - 60%

**TABLE 2****Indoor Air Test Results – Wachusett Regional High School, Holden, MA – October 7, 2005**

<b>Location</b>	<b>Carbon Monoxide (*ppm)</b>	<b>TVOCs (*ppm)</b>	<b>Ultrafine Particulates (**1000p/cc<sup>3</sup>)</b>	<b>Remarks</b>
Background at Front Entrance	1	ND	23	Warm, humid, cloudy, cars idling, construction activity
2 <sup>nd</sup> Floor Hallway Center	1	ND	22.6	
Construction Barrier 2 <sup>nd</sup> Floor Hallway	1	ND	60	Elevated UFCs around seams of construction barrier-drafts/light penetrating
2 <sup>nd</sup> Floor Boys Restroom	1	ND	125	Cigarette smoke, exhaust vents not operating
Background Outside Lower Level Classrooms	3	0.2	52	Construction vehicles operating heavy traffic load due to pouring of concrete
9	3	1.0	9.8	UV-on, exhaust-off
7	3	1.2	13.4	UV-weak, exhaust-off
5	6	1.0	36	Birds nest over temporary doorway-open spaces to the outside, space under exterior door, exhaust-off, class at lunch
Lower Level Hallway	7	1.0	65	HEPA filtration units drawing air from outside through gaps in

**\* ppm = parts per million**

**\*\*1000p/cc<sup>3</sup> = parts per cubic  
centimeter**

**TABLE 2**

**Indoor Air Test Results – Wachusett Regional High School, Holden, MA – October 7, 2005**

<b>Location</b>	<b>Carbon Monoxide (*ppm)</b>	<b>TVOCs (*ppm)</b>	<b>Ultrafine Particulates (**1000p/cc<sup>3</sup>)</b>	<b>Remarks</b>
				construction barriers, pressurizing hallway air into classrooms
207	1	ND	19	Windows open, construction vehicles operating, UV and exhaust vent-not operating
Temporary Cafeteria Hallway				Spaces/gaps at ends of construction barrier
Cafeteria/gym	2	ND	71	Stuffy, hot, exhaust inoperable, kitchen equipment/vending machines-waste heat

**\* ppm = parts per million**

**\*\*1000p/cc<sup>3</sup>= parts per cubic centimeter**